

Respiratory Effects of Household Exposures to Tobacco Smoke and Gas Cooking¹⁻³

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Introduction

Domestic air pollution must have been a human health problem since the time that cave-dwelling hominids first built fires. Only recently, however, have such effects been documented. Smoke from fires in huts has been implicated as a cause of chronic respiratory disease both in India and in New Guinea (1, 2). In more modern homes, tobacco smoke produced by others, clearly an annoyance to many non-smokers, and fumes from cooking fuels are now coming under suspicion as causes of respiratory symptoms and reduced ventilatory function.

Both these sources of domestic air pollution have been shown to produce potentially damaging pollutants. Respirable particulates have been found to be higher in homes of smokers (3), and higher concentrations of nitrogen dioxide were recorded in homes where gas was used as a cooking fuel than in homes using electricity for cooking (4, 5). But the extent to which smoking by others or cooking with gas are detrimental to human health is a question that is still unsettled, largely because of the difficulties in measuring individual exposures and because of inconsistent findings.

Most of the subjects for studies of such exposures have been children. Studies using frequency of illnesses as an outcome measure agree that children from homes with smokers are more likely to have respiratory illnesses than those not exposed to tobacco smoke at home (6-14). Some doubt is cast on the specificity of this relationship, however, by findings that nonrespiratory illnesses were also more common among the children of smokers, although this excess could have occurred by chance (6, 8). Respiratory symptoms among children were reported by 4 studies, 3 finding an association with smoking by family adults (9, 15, 16), whereas one stated

SUMMARY The records of 1,724 residents of Washington County, Maryland, who had participated in 2 studies of respiratory symptoms and ventilatory function were analyzed to evaluate the effects of exposures at home to tobacco smoke generated by other members of their households and to fumes from the use of gas as a cooking fuel. Currently smoking subjects showed the highest frequency of respiratory symptoms and impaired ventilatory function; former smokers showed a lower frequency of these findings; and persons who had never smoked had the lowest prevalence of abnormal respiratory findings. The presence of a smoker in the household other than the subject was not associated with the frequency of respiratory symptoms, and only suggestively associated with evidence of impaired ventilatory function. The use of gas for cooking was related to an increased frequency of respiratory symptoms and impaired ventilatory function among men, being most marked among men who had never smoked. There was no evidence that cooking with gas was harmful to women.

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that no association was found but did not show the data on which this statement was based (17). Of 4 studies of ventilatory function (13, 16-18), 2 found an association with parental smoking (16, 18).

The effect of smoke produced by others, so-called involuntary smoking, on adults is even less clear. In Tucson, and in 3 small towns in the eastern United States, respiratory symptoms were not associated with exposure to tobacco smoke in the home (9, 17). The latter study found ventilatory function to be unrelated to involuntary smoking. In contrast, a third study of adults found evidence of airways obstruction among persons exposed to involuntary smoking at home (19).

There are also disagreements regarding the respiratory effects associated with gas cooking. In England and Scotland, and in 6 cities in the United States, children living in homes using gas for cooking were more likely to have had respiratory illnesses than those from homes using electricity (11-13). This association was not found in Columbus, Ohio, and in Long Island, New York (20, 21). Ventilatory function was found to be diminished among persons living in homes with gas cooking in 1 study (13) but not in 2 others (12, 20).

Whether or not domestic air pollution is hazardous to health is an issue

for preventive medicine and public health that needs to be resolved by additional and continued studies. The potential hazards of gas cooking and of involuntary smoking can both be controlled, the former by adequate stove ventilation (5) and the latter by providing additional incentives for smokers to quit and nonsmokers not to start. As energy-saving incentives increase, the potential importance of domestic air pollutants will also increase as home improvements decrease the dilution of household air by infiltration.

Methods

The subjects for this study were 1,950 adult residents of Washington County in western Maryland who were examined in 1977 in 2

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separate but related studies. One of these was a comparison of 3 standardized questionnaires: a respiratory questionnaire newly developed by the American Thoracic Society for the Division of Lung Diseases, National Heart, Lung and Blood Institute (22); the original version of the questionnaire used by the National Heart, Lung and Blood Institute (23); the 1976 version of the British Medical Research Council questionnaire (24). The 3 questionnaires were found to produce similar frequencies of histories of chronic cough and chronic phlegm. The new American Thoracic Society—Division of Lung Diseases questionnaire elicited more complaints of wheeze, whereas the older questionnaire used by the National Heart, Lung and Blood Institute elicited more mild breathlessness than the other 2 (25).

The 1,004 subjects for this questionnaire study were selected from the respondents to a health census of Washington County done in the summer of 1975 (25). Enumeration of residents is estimated to have been 89% complete. Selections of study subjects were made from the census lists in a way that produced samples of subjects for each of the 3 questionnaires that were similar in size and composition with respect to age, sex, race, rural residence, education, and cigarette smoking. Approximately three quarters of each sample were cigarette smokers. Although the selection process was too complex to allow definite statements as to representativeness, there was reason to believe that the subjects in each of the small subcategories of the samples did not differ from all enumerated residents in the same subcategories by more than chance variation.

The second group of 946 subjects were participants in a longitudinal study of white men who participated in a private census of Washington County in 1963 and who were 35 to 65 yr of age at that time (26, 27). Participation in that census was estimated to have been better than 98% complete. Subjects for the longitudinal study were selected to provide a representative sample of men who did and did not smoke cigarettes and who were residents of the county areas in and adjacent to the city of Hagerstown. All of the subjects in the longitudinal study were administered the new questionnaire developed by the American Thoracic Society.

The questionnaire study was done in the spring and summer of 1977. Approximately 40% of the subjects completed questionnaires that had been mailed to them; the others were interviewed by telephone. In the longitudinal study, all subjects were interviewed in person during the summer or autumn of 1977. Interviewers for both studies were carefully trained in the use of the questionnaires.

Ventilatory function testing was done in over half of the subjects in the questionnaire study and in virtually all of those in

the longitudinal study. Five satisfactory blows by the standing subject into a calibrated Stead-Wells spirometer were recorded (28). Both forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC) were calculated, as was the ratio of observed to predicted FEV₁. Corrections were made for temperature. For our analyses, only the best of the 5 values were used. Predicted values were calculated, using the data of Goldman and Becklake (29), to adjust for age, sex, and height.

Household exposures were assessed from information recorded in the health census of 1975. Information was available on smoking histories of adult household members, the use of gas as a cooking fuel, air conditioning, the number of adults and children in the household, and the number of rooms. Several calculated indexes were used: persons per room, children under 15 yr of age per household, ever-smokers per room and per household, and current cigarette smokers per household. Years of school completed and number of bathrooms in the household were used as indicators of socioeconomic status.

Six groups were selected for final analysis. Their derivation from the 1,950 subjects in the 2 original studies is shown in a flow diagram (figure 1). Most of the exclusions occurred among longitudinal study participants, 15% of whom were not identified in the 1975 census. Some households contained 2 index persons. Because of their small number, the simplest method of handling this potential problem was to exclude them from the analysis. Another small group of persons was dropped because of incomplete information on their respiratory questionnaires, virtually all involving mailed questionnaires. The final 6 study groups consisted of 426 men and 113

women who had never smoked cigarettes, 199 men and 33 women who had formerly smoked cigarettes, and 644 men and 309 women who currently smoked cigarettes.

To adjust findings for the effects of potentially confounding factors, binary variable multiple regression was used, as described by Feldstein (30) and adapted for epidemiologic use by Shah and Abbey (31). This regression method does not assume that relationships are linear and minimizes the effect of extreme values. It does assume that the contributions of the independent variables are additive.

Results

Characteristics of the subjects in the 6 study groups are shown in table 1. Differences in distribution of characteristics between men and women resulted largely from the fact that the males represented 2 study populations with different criteria for selection, since the longitudinal study involved only men, while the questionnaire study population was composed of nearly equal numbers of each sex. Differences between persons who never smoked, former cigarette smokers, and current cigarette smokers also reflected differences between the kinds of persons who selected themselves into these 3 smoking categories. The distribution of current smokers by amount smoked was caused in part by over-sampling heavy smokers for the questionnaire study. Because of the resulting differences between the study groups, their experiences were analyzed separately as proportions of persons

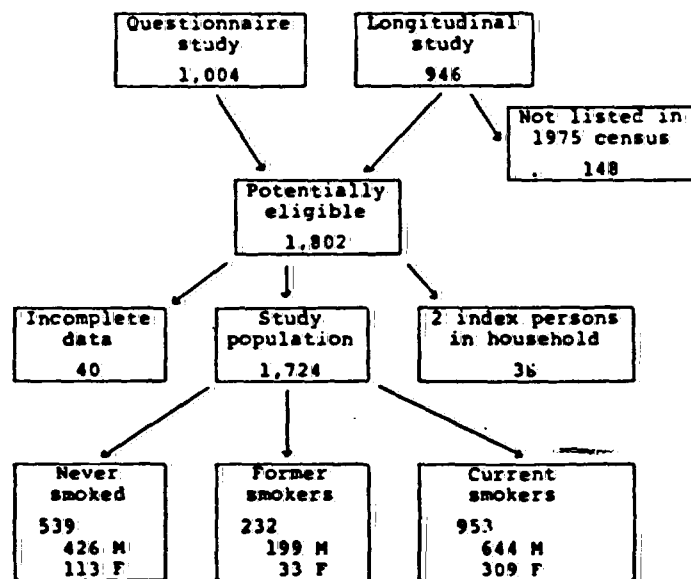


Fig 1. Derivation of study populations

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TABLE 1
PERCENTAGE DISTRIBUTION OF SUBJECTS IN STUDY GROUPS BY SEX, CIGARETTE SMOKING HISTORY,
AND OTHER SELECTED CHARACTERISTICS

Characteristics		Men			Women		
		Never Smoked	Exsmokers	Current Smokers	Never Smoked	Exsmokers	Current Smokers
Number of subjects		426	199	644	113	33	309
Age in 1975	20-34	8.2	5.0	15.5	35.4	33.3	35.6
	35-44	9.2	7.5	15.1	23.9	12.1	29.1
	45-54	34.5	38.2	42.2	31.0	27.3	25.6
	55-64	31.9	32.2	22.4	9.7	27.3	9.7
	65+	16.2	17.1	4.8	0	0	0
Education	< 12	30.3	53.3	46.6	48.6	27.3	51.8
	12	31.7	25.6	33.1	31.9	45.5	27.8
	> 12	38.0	21.1	20.3	19.5	27.3	20.4
Number of bathrooms	1 or less	54.2	69.3	71.0	73.5	57.6	69.9
	> 1	45.8	30.7	29.0	26.5	42.4	30.1
Persons/room	< 0.5	48.1	44.7	37.3	27.4	36.4	27.8
	> 0.5	51.9	55.3	62.7	72.6	63.6	72.2
Children < 15	0	68.5	74.9	57.5	45.1	45.5	39.5
	1+	31.5	25.1	42.5	54.9	54.5	60.5
Air conditioning	Yes	67.1	65.3	59.2	54.9	57.6	59.9
	No	32.9	34.7	40.8	45.1	42.4	40.1
Current number of cigarettes/day	0	100.0	100.0	0	100.0	100.0	0
	< 20/day	0	0	20.7	0	0	35.6
	20+ /day	0	0	79.3	0	0	64.4
Other cigarette smokers in household	No	77.7	62.3	46.1	68.1	39.4	37.9
	Yes	22.3	37.7	53.9	31.9	60.6	62.1
Cooking fuel	Electricity	74.8	63.8	65.0	62.8	69.7	61.2
	Gas	16.0	29.1	28.9	29.2	27.3	33.6
	Other	9.2	7.0	6.1	8.0	3.0	5.2

with respiratory findings, adjusted for the effects of independent variables shown in table 1.

Effect of other smokers in household. The frequency of major respiratory symptoms among subjects showed little evidence of an association with the presence of some one else in the household who smoked cigarettes (table 2). This held true regardless of sex or smoking history of the subjects. None of the relative risks nor the proportion of relative risks greater than 1.0 exceeded what could easily have resulted from chance. The presence of poor ventilatory function, defined as FEV₁ being less than 80% of the predicted value or less than 70% of the FVC, is shown in table 3. Although there is a definite tendency for persons with another smoker in the household to have impaired ventilatory function, none of the observed differences was great enough to achieve significance.

Effect of cooking fuel. The associations of respiratory symptoms with the type of fuel used for cooking are shown in table 4, again as adjusted proportions. Relative risks are shown for the comparisons of gas with electricity. Men whose households had gas

as a cooking fuel were at greater risk of having each of the respiratory symptoms than men whose households used electricity as a cooking fuel, although these risks achieved significance ($p < 0.05$) only for chronic cough, wheeze, and breathlessness of Grade 3 or more among men who never smoked. Among women, there was no evidence that exposure to gas cooking was associated with a greater risk of having respiratory symptoms than exposure to other cooking fuels. If a crude correction for multiple comparisons is made by multiplying p values by 24 (the total number of comparisons, counting cough and phlegm as one comparison because of their high correlation), only the excess risk of breathlessness of Grade 3 or more among men who never smoked cigarettes retains significance at a p value of 0.05 or less.

The adjusted proportions of persons with impaired ventilatory function as related to cooking fuel is shown in table 5. Among men who never smoked cigarettes, gas cooking was definitely associated with impaired ventilatory function, even when corrected for multiple comparisons. There were too few women who had never smoked ciga-

rettes and whose ventilatory function was tested to put any reliance in the similar association observed among them for gas cooking and diminished FEV₁. There was only slight evidence of an association of impaired ventilatory function associated with gas cooking among men who formerly smoked cigarettes, and none among men or women who currently smoked cigarettes.

Discussion

The importance of indoor sources of air pollution, such as tobacco smoke and fumes from unvented gas flames, is almost certain to increase as homes are made more and more air-tight in an effort to hold down heating and cooling costs. Although the evidence of harm from passive smoking or gas cooking is not yet conclusive, it is sufficiently suggestive among children to warrant serious consideration. Part of the difficulty in establishing an association between household exposures and respiratory symptoms among adults is that they have a variety of exposures outside of the home, such as air pollutants in the community or at work,

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TABLE 2
ADJUSTED PERCENTAGES* OF PERSONS WITH SPECIFIED RESPIRATORY SYMPTOMS BY SEX AND NUMBER OF CIGARETTE SMOKERS IN THE HOUSEHOLD EXCLUSIVE OF SUBJECTS, AND BY CIGARETTE SMOKING HISTORY.

	Number of Cigarette Smokers in Household Exclusive of Subjects					
	Men			Women		
	0	1+	RR†	0	1+	RR†
Never Smokers						
Number	331	95	—	77	36	—
% with respiratory symptoms:						
Chronic cough	8.3	8.0	0.96	6.0	1.0	0.17
Chronic phlegm	8.4	7.6	0.90	5.8	4.2	0.72
Chronic cough and phlegm	3.7	4.8	1.30	4.6	1.3	0.28
Wheeze	22.1	23.0	1.04	20.1	29.1	1.45
Breathlessness, grade 3	3.9	4.2	1.08	8.5	15.2	1.79
Chest illness in past 3 yr	12.0	11.0	0.92	24.2	23.3	0.96
Exsmokers						
Number	124	75	—	13	20	—
% with respiratory symptoms:						
Chronic cough	12.6	16.4	1.3	15.3	10.0	0.7
Chronic phlegm	13.7	21.3	1.6	8.8	9.3	1.1
Chronic cough and phlegm	7.6	14.1	1.9	8.8	9.3	1.1
Wheeze	38.0	49.1	1.3	7.4	25.2	3.4
Breathlessness, grade 3	12.2	15.8	1.3	3.3	17.9	5.4
Chest illness in past 3 yr	20.5	24.8	1.2	44.8	30.9	0.7
Current Smokers						
Number	297	347	—	117	192	—
% with respiratory symptoms:						
Chronic cough	39.4	35.2	0.89	27.9	33.0	1.18
Chronic phlegm	34.9	31.2	0.89	28.2	30.2	1.07
Chronic cough and phlegm	24.2	24.5	1.01	18.2	22.7	1.25
Wheeze	54.0	48.4	0.90	50.2	48.6	0.97
Breathlessness, grade 3	19.4	15.1	0.78	16.1	24.5	1.52
Chest illness in past 3 yr	18.1	14.8	0.82	27.3	30.8	1.13

* Adjusted for effects of characteristics in table 1 except for presence of other smokers in household.

† Relative risk associated with having a cigarette smoker other than the subject in the household.

TABLE 3
ADJUSTED PERCENTAGES* OF PERSONS WITH SPECIFIED DEGREES OF VENTILATORY FUNCTIONS BY SEX AND NUMBER OF CIGARETTE SMOKERS IN THE HOUSEHOLD EXCLUSIVE OF SUBJECTS, AND BY CIGARETTE SMOKING HISTORY.

	Number of Cigarette Smokers in Household Exclusive of Subjects					
	Men			Women		
	0	1+	RR†	0	1+	RR†
Never Smokers						
Number	291	78	—	34	15	—
% with impaired ventilatory function:						
FEV ₁ <80% predicted	5.0	7.1	1.42	8.9	0	0
FEV ₁ /FVC <70%	7.8	9.3	1.19	0	0	—
Exsmokers						
Number	114	65	—	7	10	—
% with impaired ventilatory function:						
FEV ₁ <80% predicted	9.2	16.1	1.8	0	0	—
FEV ₁ /FVC <70%	18.1	20.6	1.1	0	0	—
Current Smokers						
Number	215	257	—	49	93	—
% with impaired ventilatory function:						
FEV ₁ <80% predicted	22.8	26.1	1.14	15.8	17.5	1.11
FEV ₁ /FVC <70%	27.2	30.1	1.11	7.7	9.9	1.29

* Adjusted for effects of characteristics in table 1 except for presence of other smokers in household.

† Relative risk associated with having a cigarette smoker other than the subject in the household.

or associations with smokers in many places away from home.

Furthermore, it seems likely that an effect of household exposures will be demonstrable only among persons who have never smoked. The exposures from one's own smoking, particularly from inhaling the smoke, are many times more intense than would be tolerated in the ambient air. In the present study, as in many others, current smokers had much higher rates of respiratory symptoms than persons who had never smoked. Former cigarette smokers had rates intermediate between persons who had never smoked and current smokers, perhaps because the presence of these symptoms had induced them to stop smoking. In any case, these findings among former smokers emphasized the need to base studies of household exposures on persons who have never smoked rather than on persons who are not current smokers, a group that is a mixture of those who have never smoked and those who have quit.

The present study also suggested that effects of household exposures may be more readily demonstrable among men than among women. At first glance, this seems paradoxical, since women in this community are much less likely to work outside of the home than men, and hence are presumably more likely to be exposed to pollutants at home. But domestic air pollution is nothing new, dating back at least to the times of the cave-dwelling Cro-Magnon people. Judging from present day experiences in India and New Guinea (1, 2), smoke exposure in the home probably did not diminish greatly until stoves and furnaces came into common use only a few hundred years ago. Selective factors for resistance to smoke have thus had ample time to operate, and it seems possible that this selection might have resulted in women being less susceptible to domestic smoke and fumes than men. Whatever the reason, recent reports have indicated that deterioration in ventilatory function among cigarette smokers is less marked among women than among men (32, 33). It is also pertinent to note that one of the studies that failed to find an effect of gas cooking on adults was limited to women (20).

Because of the contradictory findings thus far reported, it is clearly desirable to look further at the prob-

TABLE 4.
ADJUSTED PERCENTAGES* OF PERSONS WITH SPECIFIED RESPIRATORY SYMPTOMS BY
SEX AND TYPE OF COOKING FUEL AT HOME, AND BY CIGARETTE SMOKING HISTORY.

	Men				Women			
	Gas	Elec.	Other	RR†	Gas	Elec.	Other	RR†
Never Smokers								
Number	68	319	39	—	33	71	9	—
% with respiratory symptoms								
Chronic cough	16.1	6.6	7.2	2.44‡	8.3	3.7	0	2.24
Chronic phlegm	10.3	8.2	5.0	1.26	4.8	6.5	0	0.74
Chronic cough and phlegm	8.7	3.1	2.8	2.81	5.2	3.7	0	1.41
Wheeze	33.9	20.0	20.8	1.70‡	29.4	21.8	9.4	1.35
Breathlessness, grade 3	11.2	2.6	2.6	4.31‡	0.2	16.7	0.7	0.01‡
Chest illness in past 3 yr	16.3	11.0	9.7	1.48	8.6	29.0	39.7	0.30‡
Exsmokers								
Number	58	127	14	—	9	23	1	—
% with respiratory symptoms								
Chronic cough	20.9	11.7	7.5	1.79	23.3	7.8	10.9	2.97
Chronic phlegm	24.8	13.7	8.6	1.81	20.0	4.9	6.5	4.08
Chronic cough and phlegm	14.9	8.0	8.6	1.87	20.0	4.9	6.5	4.08
Wheeze	52.9	40.1	18.8	1.32	14.6	20.1	5.5	0.72
Breathlessness, grade 3	18.6	11.2	14.3	1.66	16.5	11.1	0	1.48
Chest illness in past 3 yr	22.7	22.5	16.3	1.01	59.8	25.4	76.4	2.35
Current Smokers								
Number	186	419	39	—	104	189	16	—
% with respiratory symptoms								
Chronic cough	42.5	34.5	39.5	1.23	28.9	32.2	32.3	0.89
Chronic phlegm	36.7	32.5	20.5	1.13	32.3	27.0	39.6	1.20
Chronic cough and phlegm	29.1	23.2	15.1	1.25	24.1	18.3	33.1	1.32
Wheeze	51.9	50.6	50.5	1.03	52.5	46.4	60.7	1.13
Breathlessness, grade 3	18.4	17.3	8.1	1.06	27.9	17.7	22.8	1.58
Chest illness in past 3 yr	17.1	16.1	14.6	1.06	26.2	30.4	39.1	0.86

* Adjusted for effects of characteristics shown in table 1 except for cooking fuel.

† Relative risk associated with gas compared to electricity as cooking fuel.

‡ $p < 0.05$.

lem of household exposures. The specificity of the associations of respiratory findings with these exposures should be investigated to help rule out the possibility that exposed populations have other factors that cause them to have more illness in general or lead them to seek medical care more readily than the unexposed. Findings should also be reported separately for each sex, and for at least 3 groups of smokers—never, former,

TABLE 5.
ADJUSTED PERCENTAGES* OF PERSONS WITH SPECIFIED DEGREES OF VENTILATORY
FUNCTION BY SEX AND TYPE OF COOKING FUEL AT HOME,
AND BY CIGARETTE SMOKING HISTORY.

	Men				Women			
	Gas	Elec.	Other	RR†	Gas	Elec.	Other	RR†
Never Smokers								
Number	55	281	33	—	10	33	6	—
% with:								
FEV ₁ < 80% predicted	16.4	3.9	0.4	4.21‡	14.4	5.4	0	2.67
FEV ₁ /FVC < 70%	21.9	5.6	6.8	3.91‡	0	0	0	—
Exsmokers								
Number	53	113	13	—	5	11	1	—
% with:								
FEV ₁ < 80% predicted	17.9	9.0	10.7	1.99	0	0	0	—
FEV ₁ /FVC < 70%	23.1	18.0	10.8	1.29	0	0	0	—
Current Smokers								
Number	123	320	28	—	42	93	7	—
% with:								
FEV ₁ < 80% predicted	24.9	25.9	8.9	0.96	13.2	18.7	14.6	0.71
FEV ₁ /FVC < 70%	32.4	29.6	4.9	1.09	10.8	9.4	0	1.29

* Adjusted for effects of characteristics in table 1 except for cooking fuel.

† Relative risk associated with gas compared to electricity as cooking fuel.

‡ $p < 0.001$.

and current. Adjusting for these factors may obscure a real association in one of the subgroups. Exposures outside the home should also be taken into account whenever possible.

An additional incentive for establishing whether or not household exposures to tobacco smoke and gas cooking are important is that both are remediable. Venting gas stoves can markedly reduce concentrations of oxides of nitrogen in the home (5). The possibility that smoking may harm others, especially children, should increase motivation for smokers to quit and nonsmokers not to start. Perhaps the Victorian custom of smokers retiring to a specified room to indulge their habit should be reinstituted, particularly if that space can also be vented to the outside.

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